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this river, and we cannot but wish him every success in his dangerous but extremely important task. In his letter, above quoted, he mentions a tribe of Indians, the Anaguas, but I am not quite sure whether the word commences with A or O. It may be Omaguas, which would make them a fragment of the race of this name which once occupied such a vast region on the upper Amazon and the rivers of Ecuador. If some of them are still found at the headwaters of the Guaviare, it is interesting to ethnologists.

REPORT OF PROGRESS IN THE INVESTIGATION OF RIVERS.*

By A. STRAHAN, Sc.D., F.R.S.

THIS investigation was commenced in 1906 by aid of a Government grant of £150 per annum for three years, supplemented by a grant of £50 by the Royal Geographical Society. The object is to ascertain—

(*a*) The discharge of rivers in winter and summer, and the total annual discharge.

(*b*) The suspended and dissolved impurities in wet and dry periods, and the total amount carried in the year.

(*d*) The rainfall in different parts of each river-basin.

(*e*) The area of each basin, and the elevation of different parts of it.

(*f*) The area occupied by calcareous and non-calcareous formations, and by pervious and impervious formations.

At my invitation, Dr. A. J. Herbertson and Dr. H. R. Mill joined me as a committee, the latter undertaking to furnish records of the rainfall. Subsequently, Mr. N. F. MacKenzie consented to become a member of the committee, and to give the benefit of his wide experience in gauging rivers and canals in India.

The committee have had also considerable assistance from Mr. E. F. Elton and Mr. H. O. Beckit in many branches of the work, more especially in levelling, sounding, and measuring river-channels, in tracing water-partings, and in the computation of areas.

To Prof. W. H. Lewis, of the Albert Memorial College, Exeter, the committee is indebted for periodical examinations of the suspended and dissolved impurities in the Exe.

THE EXE AND ITS TRIBUTARIES.

Work was commenced on the Exe. The Exeter City Council, in reply to a letter describing the nature of the investigation, promised assistance in every possible way as far as it related to this river. A gauge, furnished by the committee, was fixed by Mr. Thomas Moulding, the city surveyor, at Exeter quay, and is being read daily by one of his staff. The river is here confined to a single channel of fairly uniform breadth and depth, and seemed suitable for determinations of volume. The channel was therefore sounded for a measured length of 100 feet, and velocity-observations have been made as frequently as possible. A record of floods since 1866 has been kept at a boat-house close by. By levelling from the flood-marks to the gauge the committee has been able to add this record to its recent observations.

* Research Department, November 15, 1907.

About 5 miles above Exeter, the Exe receives the Creedy on its right bank, and the Culm on its left bank. Gauges have been erected on both of these rivers, and on the Exe above the confluence, and are being read daily. Velocity-courses have been measured on the Creedy and the Exe close to the gauges, and observations on the current have been made when practicable. The course on the Exe seems to be satisfactory, but that on the Creedy may have to be changed, inasmuch as flood-water of the Exe may under certain conditions run up the Creedy as far as the spot selected. The Culm presents considerable difficulties, for when in flood it spreads over a broad alluvial flat and fills a number of temporary channels. The best method of dealing with this stream is still under consideration. In the mean time the gauge is read daily by Mr. Charles Gray, engineer to the Silverton Paper Mills, who has kindly also consented to collect samples of water periodically. The Creedy gauge was fixed and is read by men in the employment of the city surveyor.

The rate of passage of floods down the Exe being a matter of interest, the readers of the gauges have been instructed to make hourly observations when a rapid alteration of level is taking place. With the same object in view, a gauge has been erected in the Exe near Dulverton, about 22 miles above Exeter. The gauge was fixed by kind permission of Mr. T. F. Tracy at his Exe Valley Fishery, and is being read daily and hourly when desirable.

The water-supply of Exeter is taken from the Exe between these upper gauges and Exeter quay. The amount taken is known, and will be allowed for. The outflow of these rivers above their confluence, with the amount added, should approximately equal the outflow at Exeter quay.

The observations made so far by Prof. Lewis have shown that the amount of matter carried in suspension by these rivers when in normal condition is extremely small. Half a gallon of water does not yield sufficient material to weigh, and preparations are being made to collect larger quantities. No opportunity has yet arisen of examining the water of a high flood.

During violent floods sand and gravel are rolled along the bottom. No reliable method of determining the amount rolled has ever been devised, but, in the case of the Exe, the committee hope to get a satisfactory estimate by aid of the city surveyor. For some years gravel has been dredged from a reach above Exeter in just sufficient quantity to keep the channel at a constant depth. A record of the amount dredged is promised to the committee.

The areas of the Exe basin above Exeter quay, and of the Creedy, Exe, and Culm basins above the upper gauges, are being measured on the 6-inch maps by Mr. E. F. Elton. This necessitated an examination on the ground of much of the water-parting by Mr. Elton and Mr. Beckit, it having proved to be impossible to determine the parting with sufficient accuracy on any existing map. At the same time computations of the areas above and below certain altitudes, and of the areas occupied by various geological formations, are being made.

The Medway.

The Medway having been canalized, its flow is controlled by sluices and affected by the working of locks. Occasional observations on the water-level or on the current are therefore useless, and attempts are being made to obtain a continuous record of the water-level at two spots about 1½ mile apart. For this purpose two water-level recorders, worked by clocks, have been established, one by permission of Mr. W. E. Martin in his garden in Maidstone, the other by permission of Mr. Randall Mercer in his boathouse near Allington lock. The relative level of the gauges is being determined, and the capacity of all parts of the channel between them will be ascertained as soon as practicable.

The committee is also making arrangements for the collecting and examining of samples of the water in the various conditions of the river. The amount of suspended matter carried by the Medway appears to be far greater than that carried by the Exe, and great importance is attached to the obtaining of reliable data.

The committee desire to express their obligation, not only to the gentlemen named above, but to the Lower Medway Navigation Company. By permission of the chairman, Mr. John Arcoll, the site was prepared for the lower gauge by the staff of the Navigation Company, under the superintendence of Mr. John Rose, their lock-keeper at Allington.

It is to be regretted that considerable irregularities in the clocks have delayed the commencement of a continuous record. Detection of the cause of error necessitated frequent journeys to Maidstone, and in this the committee are now receiving the assistance of Lieut.-General Charles Strahan, R.E.

Other Rivers.

The Severn is a river which it will be desirable to investigate as soon as possible. Some years ago the flow at Worcester was determined with great accuracy during a period of several months by Mr. G. F. Deacon. The committee contemplates the erection of a gauge at Worcester, and periodical examinations of the water under various conditions of current. Mr. Deacon has kindly consented to allow the publication of his results in connection with such observations as may be made by the committee.

It will be desirable, also, to investigate a river which drains a chalk area, such possibly as the Salisbury Avon, with a view to ascertaining the effect of so absorbent a material as chalk on the relation of rainfall to flow-off.

In conclusion, the committee desire to call attention to their urgent need for volunteer observers. Velocity observations should be made as frequently as possible during the rainy seasons. The courses having been measured and staked out, the actual observations are easily and quickly made. Travelling to the spot constitutes the most serious part of the work, but in all cases the courses have been selected as far as possible with a view to their accessibility. In all other branches of the work, also, further assistance is urgently wanted. Rainfall observers in the upper parts of the valleys of all the rivers named could render useful services, and more rainfall observers are required in the case of the Salisbury Avon in particular.

NOTE ON MEASUREMENT OF AREAS IN THE EXE BASIN.

By E. F. ELTON.

The geology of the Exe basin having been put upon the 6-inch map, it was necessary to insert the boundary of the basin. This was generally fixed closely enough by the data of the map; where these data were insufficient I walked over the ground, and thus put upwards of 70 miles of watershed on to the map in the field. In one case the observed line differed from what the map suggested by a plot of some 200 acres; this was exceptional, but the aggregate change was considerable. This suggests that watersheds would be an interesting and useful addition to the Ordnance maps.

The basin requires 133 sheets. These vary much in dimensions. Of the fifty-four measured up to the present, only four have both dimensions correct. The variations range from 0·01 foot of shrinkage to 0·012 foot of stretching. As I am using an Amsler's planimeter with an adjustment for such variations, they do not add materially to the labour.

The measurements are checked as each sheet is finished. The error is in the fourth (rarely the fifth) figure, which, considering the other elements involved, appears to be a satisfactory result; and this error distributes over the various sections of the sheet in proportion to their area.

NOTE ON THE MEASUREMENT OF DISCHARGES OF THE EXE AND MEDWAY RIVERS.

By N. F. MACKENZIE, M. Inst. C.E.

THE discharge of any channel is given by the area of its cross-section multiplied by its mean velocity. The area of the section is got by direct measurement, and the problem that presents itself is therefore the determination of the mean velocity. This may be arrived at in various ways, of which the most usual are—

From velocity-rod observations.
From current-meter observations.
From surface velocities.
From the slope of the water-surface.
From velocities at different depths got by sub-surface floats.

The velocity of a floating weighted rod reaching from the surface nearly to the bed is found, by experiment, to be for all practical purposes the mean velocity of the vertical plane in which it moves, and velocity-rods are almost universally used in India for the measurement of canal discharges. Unfortunately, river-beds are, as a rule, too irregular to admit of their use.

Under favourable conditions, the current-meter may be expected to give good results, but the men on whom we have to rely for the observations have had no previous experience in its use; and, apart from this, the time occupied by current-meter observations is far greater than we could expect them to place at our disposal.

It was therefore decided that, whenever possible, the mean velocity should be calculated from observed surface velocities, using a coefficient or reduction multiplier. The coefficient varies with the *rugosity* of the channel, a term which includes all obstructions or irregularities which interfere with the free flow, and it also varies with the hydraulic radius of the channel. The coefficient is therefore not constant even in channels of the same rugosity, nor in the same channel for different gauge-readings.

In selecting a coefficient for reducing surface velocity to a mean velocity, we fortunately have accurate data at our disposal. For many years Indian irrigation engineers have experimented on the relation between surface and mean velocities, and on these experiments are based tables of coefficients which are accepted as correct for all purposes of discharge calculation. Indeed, some irrigation engineers consider that surface-velocity observations give results even more reliable than those obtained from velocity-rods.

The difficulty in the method lies in the proper determination of the rugosity of the channel. This is a matter of expert knowledge, but is comparatively easy for any one who has had experience in this method of measuring discharges.

Measurement of the surface velocity presents no difficulty. The river is divided into longitudinal sections, and floats are run over a measured distance, usually 50 or 100 feet, the time of passage being noted. The mean of several runs is taken for each section, and the length of run divided by the time of passage gives the surface velocity of the section.

Having obtained a series of measured discharges for various gauge-readings,

a discharge-table is drawn up by interpolation, due allowance being made for the variations of the coefficient owing to the altered value of the hydraulic radius. The above is the method adopted for the Exe and its tributaries.

On the Medway, which is canalized, the conditions are different, and a gauge reading gives no indication of the volume of water passing down the river, as navigation depth is maintained by manipulation of the lock-sluices, whatever may be the discharge. It was therefore decided to calculate the discharge from the slope of the water-surface, the slope being got from two gauges at a known distance apart, with their zeros fixed at known levels for comparison. As the conditions governing the surface slope are continually altering, it is necessary that the gauges should be self-recording.

Given the slope of the water-surface, the mean velocity is got from the expression $v = C\sqrt{RI}$, where R is the hydraulic radius, and I is the fall of the water-surface in unit-length. C is a coefficient which varies with the rugosity, surface slope, and hydraulic radius. The equation for C which it is proposed to use is the well-known formula of Kutter, which is based on the experimental investigations of Kutter and Ganguillet—

$$C = \frac{\left(41{\cdot}6 + \frac{1{\cdot}811}{N} + \frac{0{\cdot}00281}{I}\right)\sqrt{R}}{\sqrt{R} + N\left(41{\cdot}6 + \frac{0{\cdot}00281}{I}\right)}$$

where N = Kutter's coefficient of rugosity.

Calculations based on this somewhat formidable expression are much simplified in practice by the use of hydraulic tables, such as those of Higham or of Jackson, in which values of C are worked out for channels of various sizes, slopes, and degrees of rugosity. Intermediate values to suit existing conditions can be obtained by interpolation between the values given in the tables.

As in the case of the Exe, the selection of the proper coefficient of rugosity is the difficult part of the problem. The most satisfactory method will be to measure one or two discharges by the surface-velocity method, and from these calculate the appropriate value of the coefficient, which will then be applied to the surface slopes from the gauge records.

As regards the probable accuracy of the selected methods, it has been found by actual experiment on Indian canals, that surface velocities give discharges varying by not more than half per cent. from those deduced from velocity-rod observations.

The surface-slope method of calculation is more adversely affected by an error in the estimated value of the coefficient of rugosity, but if the appropriate coefficient for the Medway be determined by measurement of surface-velocity discharges, the error is not likely to exceed 1 per cent.

ON THE OBSERVATIONS OF RAINFALL.

By HUGH ROBERT MILL, D.Sc.

THE voluntary rainfall observers in all parts of the country furnish data which make it easy to produce small-scale maps showing the monthly or annual rainfall of the British Isles as a whole with considerable accuracy; but when comparatively small areas are dealt with on a large scale, the chance distribution of observers often fails to allow a satisfactory map to be drawn. I have accordingly endeavoured to enlist the services of new observers in the Exe and Medway valleys, so as to fill

up the larger gaps and make it possible to determine the volume of rainfall of any year or month with considerable accuracy, and that of any day with fair accuracy.

There are now at work in the Exe valley or on its margin, sufficiently near the watershed to give useful indications, fifty-four observers of rainfall, most of whom keep daily records. In the Medway valley the representation is equally good, and it was only found necessary to supply rain-gauges from the funds of the committee to six altogether.

The comparison of rainfall with stream-flow will involve considerable difficulty, as the general fall over the whole valley on any one day cannot affect the stream at the point where it is gauged at the same time. It will probably be found necessary to discuss heavy local rains in different parts of the basin in some detail, in order to ascertain how soon the rain finds its way down the stream, and to be guided by the result in carrying on the more general discussion. It is desirable to wait until a considerable number of heavy falls have occurred within the period of the river gaugings before proceeding to make this comparison. At present the accumulation of data is proceeding in a satisfactory way.

OBSERVATIONS OF GLACIER MOVEMENTS IN THE HIMALAYAS.

We quote below, with a few omissions and additions, the Introductory Report furnished by Mr. T. H. Holland, F.R.S., Director of the Geological Survey of India, to the detailed descriptions of the work recently carried out by his officers * in the observation of the movements of Himalayan glaciers.

"In 1905 Mr. D. W. Freshfield, on behalf of the Commission Internationale des Glaciers, drew the attention of Lieut.-Colonel S. G. Burrard, F.R.S., Superintendent of Trigonometrical Surveys, to the importance of recording data for determining the secular movements of the principal Himalayan glaciers. As the work required the co-operation of all officers and private travellers likely to visit the glacier regions of the Himalaya, Colonel Burrard referred the question to the Board of Scientific Advice, and, on the recommendation of a sub-committee composed of Colonel F. B. Longe, R.E., Surveyor-General, Dr. G. T. Walker, F.R.S., and myself, the Board agreed on a system of observations, recommending that the distribution of the necessary information and collection of data should be under the control of the Geological Survey Department. The proposals having received the sanction of the Government of India, the first step in the investigation was taken by the deputation of five Geological Survey officers during August and September, 1906, to make a preliminary survey of the principal glaciers in the Kumaon, Lahaul, and Kashmir regions.

"Altogether twelve glaciers were examined, as follows:—

"*Kashmir Region.*—The Barche and Hinarche glaciers in the Bagrot valley; the Minapin, Hispar, and Yengutsa glaciers in the Nagir State; and the Hassanabad glacier in Hunza. These six were surveyed by Mr. H. H. Hayden.

"*Lahaul.*—The Bara Shigri and Sonapani glaciers were examined by Messrs. H. Walker and E. H. Pascoe.

"*Kumaon.*—The Pindari, Milam, Shan Kulpa, and Poting glaciers were surveyed by Messrs. G. de P. Cotter and J. C. Brown.

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* 'Records of the Geological Survey of India,' vol. **35**, parts 3 and 4. 1907. London: Messrs. K. Paul, Trench, & Co.; Calcutta: Geological Survey Office.